

# Bibliometric analysis of the advances in the area of engineering and materials on rural roads

## *Análisis bibliométrico de los avances en el área de ingeniería y materiales en carreteras rurales*

*Cristian Camilo Osorio Gómez<sup>1</sup>*

*Daniel Aristizábal Torres<sup>2</sup>*

*Alejandro Alzate Buitrago<sup>3</sup>*

*Cristhian Camilo Amariles López<sup>4</sup>*

<sup>1</sup> Researcher, ccosoriog@unal.edu.co

<sup>2</sup> Reserch Center, Universidad Libre Seccional Pereira, daniel.aristizabalt@unilibre.edu.co

<sup>3</sup> Researcher, Universidad Libre Seccional Pereira, alejandro.alzateb@unilibre.edu.co

<sup>4</sup> Researcher, Universidad Libre Seccional Pereira, cristhian.amariles@unilibre.edu.co

## Abstract

The term rural roads refer to the road network that is not part of urban environments, characterized by low traffic, by interconnecting communities located in towns and villages, allow access to the agricultural market and the design speed is less than higher-ranking routes. Rural roads are extremely important infrastructure for the social and economic development of rural communities, often located in mountainous or semi-desert places, where access to basic health and education services is very complex. In this paper, a bibliometric analysis has been applied to the theme of rural roads to identify the most important trends and influences, facilitating an organized view of the peculiarities and developments in their field of research. Consequently, a total of 433 publications made between 1968 and 2020 related to the term rural roads in Scopus were identified. The 433 publications contain 878 authors, 176 journals, 41 countries or territories, and 321 institutions. From the analysis completed, four main research areas related to the rural roads research topic stand out; factors that generate risk of accidents in rural roads, technology of rural road construction materials, technological advances in vehicles for rural roads and level of environmental, social and economic impact of rural road infrastructure. In the publications, it was determined that the most relevant journals are Accident Analysis and Prevention (UK) and Transportation Research Record (USA), the most important publications are by Bella (2008) and Misaghi (2005). Additionally, the countries that produce the most research related to rural roads are China, the United States and India. Also, it can be inferred that research collaboration between authors about rural roads is high, especially between the continents America, Europe and Asia.

**Keywords:** *Bibliometric analysis, rural road, accidents, speed, automobile drivers, risk analysis, geometric design of roads.*

## Resumen

El término carreteras rurales hace referencia a la red de carreteras que no hace parte de los entornos urbanos, caracterizándose por su bajo tráfico, por interconectar comunidades localizadas en pueblos y villas, permiten el acceso al mercado agropecuario y su velocidad de diseño es menor a las vías de mayor jerarquía. Los caminos rurales son infraestructura de extrema importancia para el desarrollo social y económico de las comunidades rurales, muchas veces localizadas en sitios montañosos o semidesérticos, en los que el acceso a los servicios básicos de salud y educación es muy complejo. En este artículo, se ha aplicado un análisis bibliométrico a la temática de las carreteras rurales para identificar las tendencias e influencias más importantes, permitiendo una visión organizada de las peculiaridades y los desarrollos en su campo de investigación. Por consiguiente, se identificaron en total 433 publicaciones realizadas entre los años 1968 y 2020 afines al término carreteras rurales en Scopus. Las 433 publicaciones contienen 878 autores, 176 revistas, 41 países o territorios y 321 instituciones. Del análisis efectuado sobresalen cuatro áreas de investigación principales dentro de la temática de investigación relacionada con carreteras rurales; factores que generan riesgo de accidentalidad en las vías rurales, tecnología de materiales de construcción de carreteras rurales, avances tecnológicos en vehículos para carreteras rurales y nivel de impacto ambiental, social y económico de la infraestructura vial rural. Dentro de las publicaciones se determinó que las revistas más relevantes son Accident Analysis and Prevention (UK) y Transportation Research Record (USA), las publicaciones clave son de Bella (2008) y Misaghi (2005). Adicionalmente, los países que más producen investigaciones relacionadas con carreteras rurales son China, Estados Unidos e India, y se puede inferir que la colaboración investigativa entre autores en torno a la temática de las carreteras rurales es alta, sobre todo entre los continentes América, Europa y Asia.

**Palabras clave:** *Bibliometric analysis, rural road, accidents, speed, automobile drivers, risk analysis, geometric design of roads.*

## Introduction

According to Ardanuy (2012), the purpose of science as an intellectual activity is to respond logically and systematically to questions that are regularly associated with contextual problems and that manifest themselves in adverse effects on communities, objects, or systems. This situation raises the growing challenge of systematizing, evaluating, and qualifying, from different perspectives, scientific production in all fields and applications. The first bibliometric studies were published by Cole & Eales (1917), Wyndham (1923), and Gross & Gross (1927), addressing issues of anatomy and distribution of the animal kingdom, history of science, and assessment of the impact of scientific journals related to the chemistry, respectively. In today's world scientific production, bibliometrics is gaining special interest since scientific mapping is contributing to the growth and strengthening of currents and networks of research and scientific support (Aria, & Cuccurullo 2017), in addition to contributing to the quantitative study of scientific production (Morales, 1995; Gauthier, 1998; Spinak, 2001). However, the complexity of the treatment and processing of large volumes of information requires tools that allow the flow, organization, and statistical treatment of information to be functional, reliable, and agile. According to Aria & Cuccurullo (2017), open-source tools such as bibliometrix become powerful instruments for carrying out scientific mappings. As it is programmed in R, its flexibility and possible update allow it to be integrated with other statistical R packages.

The process of identifying and evaluating trends, advances, and scientific development that has had the issue of "roads / rural roads" worldwide involves a broad scientific mapping in databases of recognized trajectory and reliability. In effect, a search for scientific articles was carried out in the Scopus bibliographic

database portal, with the search equation by topic "Rural Roads," and using the engineering and materials science thematic filter. "Rural Roads" produced 433 related articles, and according to the annual scientific production, its trend is growing and of broad scientific interest.

When mentioning rural roads, reference is made to the road network that is not part of urban environments. Their low traffic characterizes them; by interconnecting communities located in towns and villages, they allow access to the agricultural market. Their design speed is lower than that of higher-ranking roads. In general, its management, maintenance, and operation are the responsibility of the local authorities. Rural roads are critical infrastructure for rural communities' social and economic development, often located in mountainous or semi-desert places. Access to essential health and education services is very complex (Keller, & Sherar, 2004). Unquestionably, the development of rural roads accounts for the comparative advantages that a region can have, as Zhou (2020) suggests when he suggests that in the evaluation of rural roads, essential aspects such as construction, management, maintenance, and operation, as this results in its functionality and safety.

In this sense, it is crucial to consider those rural roads present a great diversity and can be categorized by design, appearance, and function (Weller, Schlag, Friedel, & Rammin, 2008). Bella (2008) and Bella (2013) emphasize their attention on speed (Liu, Huang, Wang, & Xu, 2011) and its effects on traffic, as a risk factor, through simulations. Goldenbeld & van Schgen (2005) state that the danger generated by speeding on roads, both main and rural, for people and other vehicles (Llorca, Angel-Domenech, Agustin-Gomez, & Garcia, 2017), is the same anywhere in the world, and that one of the most efficient ways to mitigate speeding violations (Martens, Compte, & Kaptein, 1997), continues to be fined for violators. This affirmation is confirmed and complemented by the studies by Kashani & Mohaymany (2011), finding that commonly

traffic accidents on the roads, as well as the severity of the effects on the occupants of the vehicles involved worldwide, are more frequent on rural roads, due to the tendency of users to exceed speed limits. However, this concept is differentiated according to risk perception (Starkey & Charlton, 2020) and each of the drivers (Goldenbeld & van Schgen, 2005). Their behavior obeys what the speed limit represents for them.

Although, the speed factor is an excellent generator of risk on rural roads, it is not the only one. The influence of rural road maintenance (Mathew, & Isaac, 2014), lane design (Russo, Busiello, & Dell, 2016), traffic and pedestrian flow (Tulu, Washington, Haque, & King, 2015), roughness (Sandamal, & Pasindu, 2020) and climatic conditions (Pokorny, Jensen, Gross, & Pitera, 2020) also play an important role when analyzing the exposure and increase in accidents on rural roads. Environmental conditions can directly affect the mechanical behavior of vehicles and the reaction capacity of drivers traveling on the roads (Drosu, Cofaru, & Popescu, 2020), in addition to technological distractors, as is the case with the use in full conduction of smartphones (Yannis, Laiou, Papantoniou, & Christoforou, 2014).

Another variable that directly influences road safety on rural roads is lighting conditions. It is vitally important to ensure that drivers can circulate in safe conditions since the road's lighting directly affects their visual capacity. Anarkooli & Hosseinlou (2016) highlighted the importance of installing lights along the route and near intersections on rural roads since the severity of injuries increases considerably when collisions occur at these points in dark conditions. Additionally, road geometry is an essential factor (Gooch, Gayah, & Donnell, 2016) and measuring the consistency of the horizontal design (Misaghi, & Hassan, 2005), in contrast to the operating speed and expected accidents. (Laam, Choueiri, Hayward, & Paluri, 1998). It is clear then that the level of safety of a road does not depend exclusively on the behavior of users in terms of compliance with traffic regulations, but also on the state

and design configuration of the rural road (Lamm, Psarianos, & Cafiso, 2002) and the signaling processes that are implemented (Loose, Franke, & Stiller, 2009). It is therefore clear that the behavior of drivers plays a transcendental role in road safety, as determined by Lehtonen, Lappi, & Summala (2012) when they suggest the importance of understanding the visualization pattern of drivers when taking curves in a rural road, as this will result in the optimization and improvement of its geometric design.

From another dimension, rural roads projects, due to the topographic characteristics and territories that they interconnect, cannot ignore the environmental, social, and economic impacts (Abd et al., 2020) that they generate since such benefits cannot be the excuse to generate effects adverse effects on the natural environment. In fact, the social and economic benefits of rural roads (Osorio-Lird, Chamorro, & González, 2020) have no discussion, as is well stated by Abhishek, van Steenberg, Fajardo Vera, Borgia, & Manjur (2020), in addition to the improvement of quality of life and gender inclusion, as the authors well argue.

Regarding the technologies of materials used in the construction of roads, there are significant advances such as those proposed by Basu, Roy, Bhattacharyya & Ghosh (2009). They realize that the materials used in the construction of rural pavements have evolved notoriously in recent years through the use not only of compacted granular materials (Jiménez, Ayuso, Galván, López & Agrela, 2012), chloride additions (Osorio-Lird, Chamorro, & González, 2020). Also, through the use of geotextiles that help to increase the bearing capacity of pavements on rural roads. Likewise, Kumar & Singh (2008) suggest using granular materials, considered as waste, to solve the problems of shortages of some raw materials.

## Materials and methods

The process of identifying and evaluating trends, advances, and scientific development that has had the topic of "rural roads/roads" worldwide involves a broad scientific mapping in databases of recognized track record and reliability. For this purpose, a search for scientific articles was carried out on the Scopus bibliographic database portal. The search equation by topic "Rural Roads," using the thematic filter engineering and materials science. The search provided a total of 433 articles, from which the scientometric and bibliometric analysis was developed using the open-source tool bibliometrix (Aria & Cuccurullo, 2017). For the analysis of bibliometric network data and data visualization, the VOSviewer software was used (Van Eck & Waltman, 2010). This action included analysis of co-authorship between countries, co-citation of authors, and co-occurrence between words.

## Results and discussion

Table 1 summarizes the totality, type, and percentage distribution of the articles corresponding to the period 1968-2020, finding that 65% of them correspond to research articles. This value indicates the enormous and growing interest that the subject has had in the scientific world and denotes the current concern for the design, operation, safety, and innovation in new materials that rural roads have throughout the world. To a lesser extent, papers for conferences (30.6%), review articles (3.0%), and articles in book chapters (1.4%) appear.

**Table 1** *Types of documents and percentage distribution*

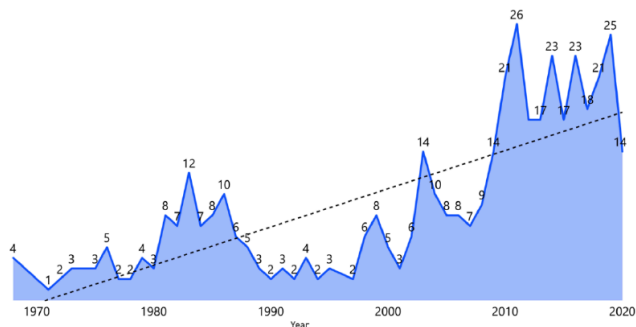
Type	Results	Distribution %
Article	282	65
Article; book chapter	6	1,4
Conference paper	132	30,6
Review	13	3,0
<b>Total</b>	<b>433</b>	<b>100</b>



## Annual Production

In terms of annual scientific production, the most productive year was 2011, with 26 articles published on the subject, while the least productive year was 1970, with only 1 article published. Additionally, there can be evidence of an increasing trend in the publication of Rural Roads from 2007 to 2020. It is necessary to bear in mind that the search was carried out before the end of 2020, and for that reason, the number of articles from 2020 could increase. The dotted line shows a growing linear trend in the publication of articles on the subject.

**Figure 1.** *Annual production*



## Most relevant countries

The scientific production by country is presented below. It can be seen that the countries with the highest number of scientific articles are China with 97, the United States, with 86, India with 56, and Spain with 35. Figure 2 a growing trend of scientific production in Europe, Asia, and South America. North. Likewise, there is deficient production on the subject in Latin America and Africa. The production of the United States is 9.55 times higher than the scientific production of the first country in Latin America, which is Chile with nine articles.

**Figure 2.** *Most relevant countries*

### Most relevant authors

The ten most relevant authors can be seen in Table 1. Cafiso S, Russo F, Bella F, Perco P, and Garca A are among the leading authors on the subject. With more articles on the subject, the author is Garca A with eight articles, followed by Cafiso S and Russo F with five. The highest registered H index is five for Cafiso S, followed by Russo F, Bella P, and Perco P with four. Goldenbeld, having only three documents, is the second author with the most citations, only below Bella F.

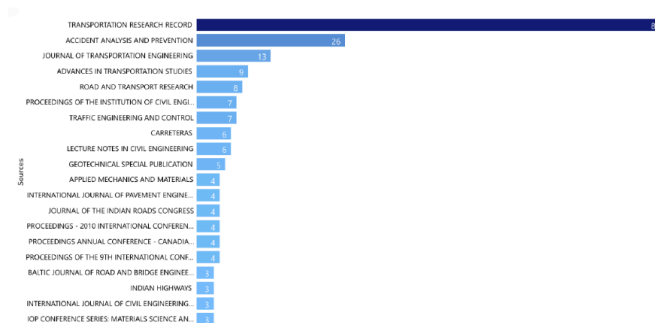
**Table 2.** *Most relevant authors*

Author	h index	g index	m index	TC	NP	PY
Cafiso S	5	5	0,263	86	5	2002
Russo F	4	5	0,500	62	5	2013
Bella F	4	4	0,308	259	4	2008
Perco P	4	4	0,267	40	4	2006
Garca A	3	6	0,375	40	8	2013
Donnell E	3	4	0,600	38	4	2016
Gayah V	3	4	0,600	38	4	2016
Berlolo N	3	3	1,000	31	3	2018
Colonna P	3	3	1,000	31	3	2018
Goldenbeld C	3	3	0,188	166	3	2005

## Most relevant sources

In Figure 3, the 20 journals with the highest number of publications are presented. 18.9% of the publications are published in the *Transportation Research Record*. The journal has some thematic areas focused on the policies, administration, economics, financing, operation, construction, safety, and designs of all transport modes. This journal triples in several articles to *Accident Analysis and Prevention*, which ranks second. There are no Latin American or African journals on the list.

Figure 3. Most relevant sources



## Most cited documents

Table 3 shows the ten most cited documents. In the first place is Bella F. "Driving simulator for speed research on two-lane rural roads" with 176 citations and its publication date is 2008 in the journal *Accident Analysis and Prevention*. The second most cited article is "Modeling operating speed, and speed differential on two-lane rural roads" by Misaghi P. and Hassan Y. with 129 citations is from 2005 in the *Journal of Transportation Engineering*. Four authors have two articles among the most cited.

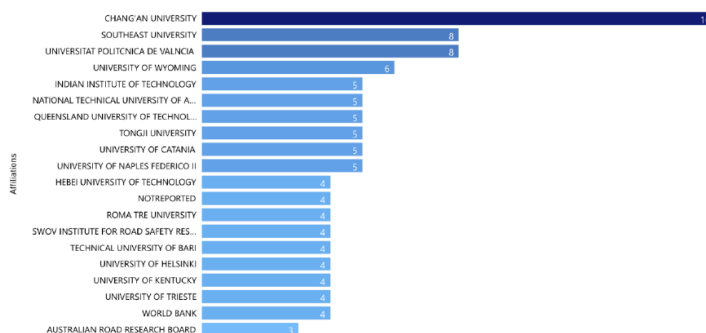
**Table 3. *Most cited documents***

Paper	Authors	Source	Year	Total citations
Driving simulator for speed research on two-lane rural roads	Bella F	Accident Analysis And Prevention	2008	176
Modeling operating speed and speed differential on two-lane rural roads	Misaghi P; Hassan Y	Journal Of Transportation Engineering	2005	129
Asnalysis of the traffic injury severity on two-lane, two-way rural roads based on classification tree models	Kashani At; Mohaymany As	Safety Science	2011	103
Safety evaluation process for two-lane rural roads: a 10-year review	Lamm R; Psarianos B; Cafiso S	Transportation Research Record	1988	87
The credibility of speed limits on 80 km/h rural roads: the effects of road and person(ality) characteristics	Goldenbeld C; Van Schagen	Accident Analysis And Prevention	2007	85
The effects of speed enforcement with mobile radar on speed and accidents: an evaluation study on rural roads in the dutch province friesland	Goldenbeld C; Van Schagen	Accident Analysis And Prevention	2005	70
Driver perception of roadside configurations on two-lane rural roads: effects on speed and lateral placement	Bella F	Accident Analysis And Prevention	2013	64
Drivers' speed behaviour on rural road curves	Kanellaidis G; Golias J; Efstathiadis S	Traffic Engineering And Control	1990	59
Kaiman particle filter for lane recognition on rural roads	Loose H; Franke U; Stiller C	Ieee Intelligent Vehicles Symposium, Proceedings	2009	56
Modeling operating speed and deceleration on two-lane rural roads with global positioning system data	Zuriaga Amp; Garca Ag; Torregrosa Fjc; D'attoma P	Transportation Research Record	2010	53

## Most relevant affiliations

The organizations that publish the most about Rural Roads can be shown in Figure 4. First, there are 16 articles Changan University located in the city of Xi'an in China. In second place is eight articles, Southeast University, located in Nanjing, China. Additionally, in third place is the Polytechnic University of Valencia with eight articles, and it is in Valencia, Spain. However, it can be seen in the table that no organization or university from Latin America is present in the top 20.

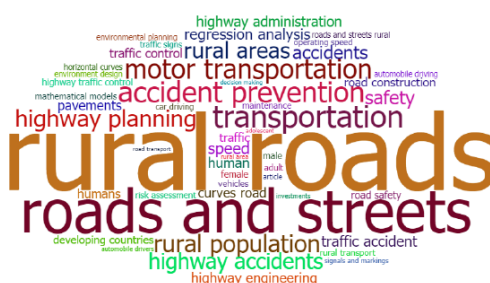
**Figure 4.** *Most relevant affiliations*



## Keywords

In Figure 5, the most relevant words within the research topic are observed. Words such as Rural Roads, Operating speed, Road Safety, and evaluation appear. The minimum number of frequency of these keywords was 3. The most frequent words denote some research trends in recent years towards reducing accidents and the planning of roads as a motor of development in some populations.

**Figure 5.** *Wordcloud*

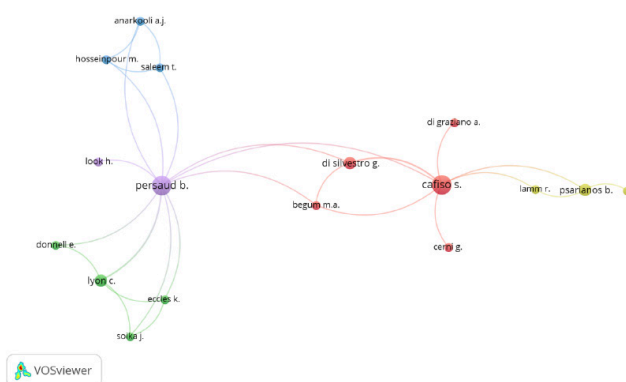


## Co-authorship analysis

Figure 6 shows the relationships and co-authorship networks found among researchers. The name of Salvatore Cafiso stands out, visible as a researcher since 2002, because apart from being

the author with the best h-index (5), the second in publications (5), and one of the most cited (86), he is perhaps the author with greater relationships, after Bhagwant Persaud, a civil engineer whose areas of research interest are road safety, geometric design, and traffic engineering. One of his five publications entitled "Microscopic accident potential models for two-lane rural roads," published in 1995 in the journal *Transportation Research Record*, has been cited 22 times. However, because it lacks DOI, its visibility and recognition as a researcher are very low. He is one of the authors with the most extended validity since his publications have been registered from 1995 to 2019, explaining that his collaboration network is the widest of all. It is striking that authors like Russo F; Bella F; Perco P; Garcia A; Donnell ET and Gayah VV, being some of the most recognized authors, do not present collaboration networks, either because of their relatively recent appearance in the research world or because their research does not have co-authorship that allows greater visibility.

**Figure 6.** *Co-authorship networks*

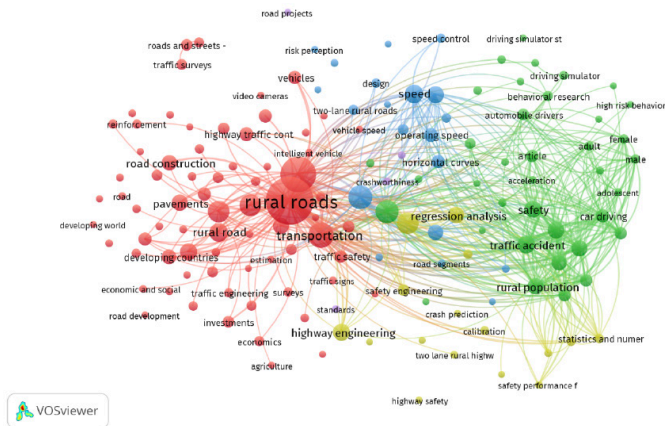


## Keyword co-occurrence analysis

Figure 7 highlights the relationships and strength of those relationships between keywords. The word "rural roads," which represents the cluster of most significant importance and density,

presents a total of 234 occurrences, 146 connections, and a link strength value of 1583, which is why it is the node with the highest visibility and associated searches. The words "roads and streets" and "transportation", with 131 links and 127 occurrences and 123 links and 67 occurrences, respectively, make up nodes of lower density since their linking forces are much lower than rural roads. Likewise, Figure 7 refers to the presence of 5 main clusters. Each one of them represents a field of particular interest in rural roads, such as rural roads, such as safety and accidents, speed, and road operation, among the most important.

**Figure 7.** *Co-occurrence of keywords*



## Conclusions

The first publications about rural roads date from 1968 and 1971. From then on, the annual scientific production grew, reaching figures of 26 articles in 2011, the year with the highest production, according to the cut made. It is necessary to make the exception that by 2020 there is a growing trend, although the bibliographic production data is not yet officially reported.

The countries with more publications on the subject are China with 97, the United States with 86, India with 56, and Spain with 35. Europe, Asia, and North America emerge in this field of scientific production. At the same time, Latin America and Africa continue to lag, despite presenting rural and territorial conditions with a high demand for rural roads.

The most cited article corresponded to the one entitled "Driving simulator for speed research on two-lane rural roads," by the author Francesco Bella (2008), affiliated with Roma TRE University, Department of Sciences of Civil Engineering.

Concerning the authors with the most significant prominence on the subject, Garca A, Kumar P, Llopis-Castell D, Cafiso S, and Camacho-Torregrosa are among the most recognized. Complementarily, the most prominent publication on the subject is the journal *Transportation Research Record*, with a record of more than 50 years. This publication focuses its interests on the policies, administration, economics, financing, operation, construction, safety, and designs of all transportation modes. According to Scimago, it has an H-index of 107 and is categorized in Q2.

With the analysis of collaboration networks, it was confirmed that these are incipient. Most of the efforts are local, isolated, and without the expected articulation between organizations and countries. The effort to generate networks between authors is highlighted.

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